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Gallatin County, Montana

National Eutrophication Survey, Corvallis, Oreg

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

HEBGEN LAKE

GALLATIN COUNTY

MONTANA

EPA REGION VIII

WORKING PAPER No. 794

WITH THE COOPERATION OF THE

MONTANA DEPARTMENT OF HEALTH & ENVIRONMENTAL SCIENCES

AND THE

MONTANA NATIONAL GUARD

MAY, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

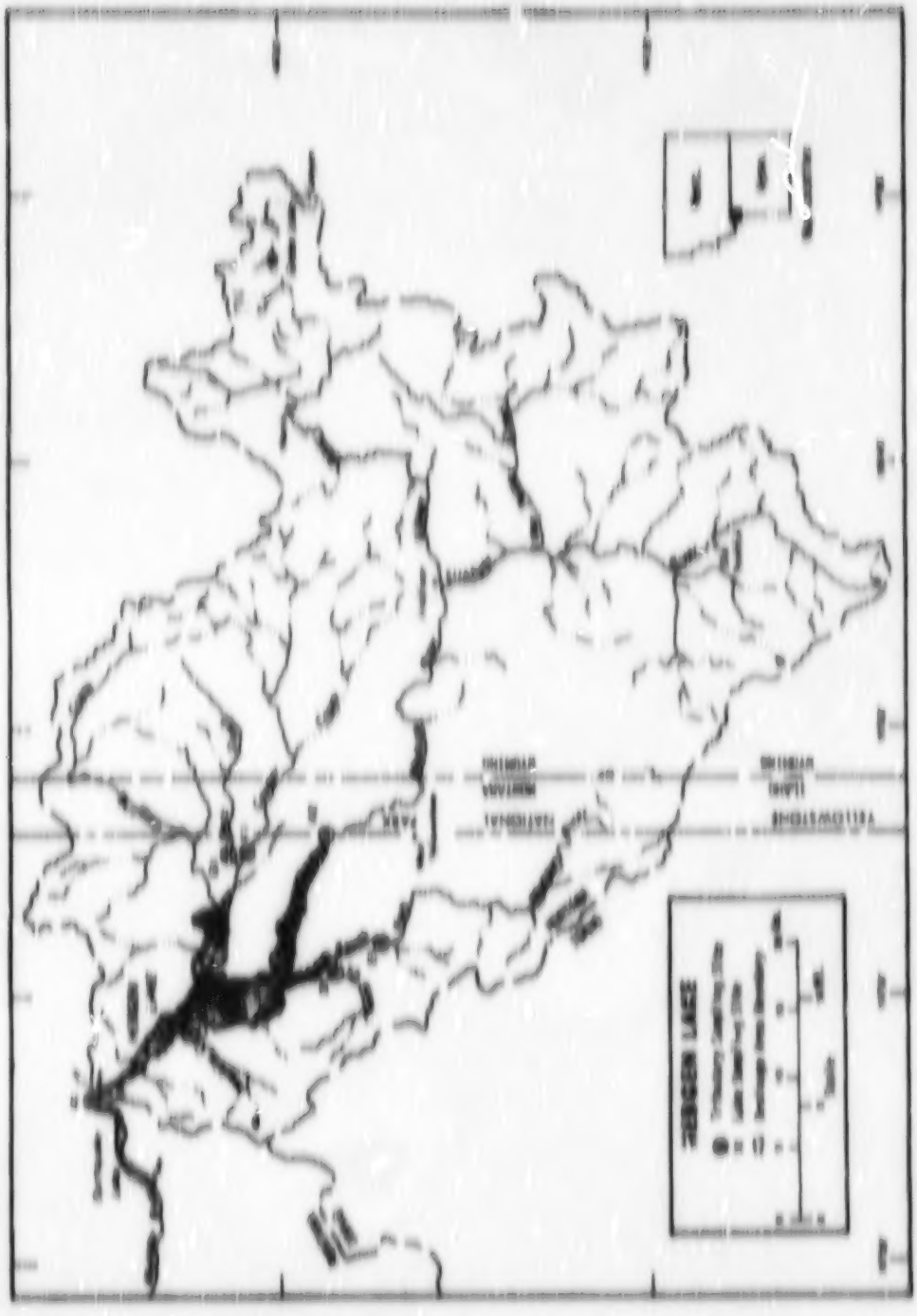
The staff of the National Eutrophication Survey (Office of Research & Development, U.S. Environmental Protection Agency) express sincere appreciation to the Montana Department of Health and Environmental Sciences for professional involvement, to the Montana National Guard for conducting the tributary sampling phase of the Survey, and to those Montana wastewater treatment plant operators who voluntarily provided effluent samples.

The staff of the Water Quality Bureau provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General John J. Womack, the Adjutant General of Montana, and Project Officer Major William Yeager, who directed the volunteer efforts of the Montana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY
STUDY LAKES AND RESERVOIRS
STATE OF MONTANA

LAKE NAME	COUNTY
Canyon Ferry	Broadwater, Lewis and Clark
Clark Canyon	Beaverhead
Flathead	Flathead, Lake
Georgetown	Deer Lodge, Granite
Hebgen	Gallatin
Koocanusa	Lincoln, MT; British Columbia, Can.
Mary Ronan	Lake
McDonald	Flathead
Nelson	Phillips
Seeley	Missoula
Swan	Lake
Tally	Flathead
Fiber	Liberty, Toole
Tongue River	Big Horn
Whitefish	Flathead
Yellowtail	Carbon, Bighorn, MT; Bighorn, WY



HEBGEN LAKE

STORET NO. 3006

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Hebgen Lake is meso-eutrophic. It ranked tenth in overall trophic quality when the 15 Montana lakes and reservoirs sampled in 1975 were compared using a combination of six water-quality parameters*. Eight of the water bodies had less and one had the same median total phosphorus, 11 had less median dissolved orthophosphorus, none had less but four had the same median inorganic nitrogen, nine had less mean chlorophyll *a*, and eight had greater mean Secchi disc transparency. Depression of hypolimnetic dissolved oxygen occurred at stations 1 and 2 in September.

Survey limnologists noted surface algal concentrations and some submerged and emergent macrophytes at stations 3 and 4 in September.

B. Rate-Limiting Nutrient:

The algal assay results indicate Hebgen Lake was nitrogen limited at the time the sample was collected (07/30/75). The lake data indicate nitrogen limitation at all sampling stations and times. In a previous study, it was noted that phosphorus levels are high and nitrogen is most likely the limiting factor in Hebgen Lake (Martin, 1965).

* See Appendix A.

C. Nutrient Controllability:

1. Point sources--No known municipal or industrial point sources impacted Hebgen Lake during the sampling year. Lakeshore septic tanks were estimated to have contributed 0.3% of the total phosphorus load to the lake, but a shoreline survey would be necessary to determine the significance of those sources.

The present phosphorus loading of 0.47 g/m^2/year is more than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as an oligotrophic loading but less than his suggested eutrophic loading (i.e., a mesotrophic loading; see page 11).

2. Non-point sources--Over 99% of the total phosphorus input to Hebgen Lake is attributed to non-point sources. The Madison River contributed 60.0%, the South Fork Madison River contributed 10.2%, Duck Creek contributed 5.0%, and Watkins Creek contributed 0.1%. Ungaged minor tributaries and immediate drainage were estimated to have contributed 19.9% of the total.

The present phosphorus export rates of the Madison and the South Fork Madison Rivers, 13 and 12 kg/km^2/year, respectively, are greater than the rates of the other tributaries of Hebgen Lake (range of 1 to 5 kg/km^2/year; see page 9). However, the higher rates most likely are due to natural sources in the drainage basin rather than unsampled point sources. A previous study showed no phosphorus decrease in the Madison River following the 1972 diversion of the seasonal discharge from the only point source in the drainage basin, the Madison Junction Plant, which served a campground at the confluence of Firehole and Gibbon Rivers (Kralich and Wright, 1974).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 51.27 kilometers².
2. Mean depth: 8.2 meters.
3. Maximum depth: 37.5 meters.
4. Volume: 420.414 x 10^6 m^3.
5. Mean hydraulic retention time: 172 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Madison River	1,157.7	13.940
Watkins Creek	29.5	0.098
South Fork Madison River	211.6	3.960
Duck Creek	305.4	1.350
Minor tributaries & immediate drainage -	653.2	9.545
Totals	2,357.4	28.853**

2. Outlet -

Madison River	2,408.7***	28.330

C. Precipitation****:

1. Year of sampling: 89.7 centimeters.
2. Mean annual: 70.6 centimeters.

† Table of metric conversions--Appendix B.
†† Norpestad, 1975.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Sum of inflows adjusted to equal outflow plus evaporation.
*** Includes area of lake.
**** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Hebgen Lake was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at four stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the July visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll *a* analysis. The maximum depths sampled were 19.2 meters at station 1, 19.5 meters at station 2, 4.3 meters at station 3, and 4.9 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table.

[illegible]

[illegible]	1ST SAMPLING (1979)			2ND SAMPLING (1979)			3RD SAMPLING (1980)		
	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN	RANGE	MEAN	MEDIAN
[illegible]	7.4 - 17.3	14.2	14.2	13.6 - 17.0	15.3	15.4	7.4 - 17.3	9.9	13.4
[illegible]	4.4 - 13.4	7.1	7.3	1.2 - 9.0	6.8	7.6	7.6 - 13.1	8.5	9.1
[illegible]	42. - 302.	174.	178.	134. - 285.	196.	178.	131. - 274.	191.	183.
[illegible]	7.5 - 9.1	8.4	8.4	7.6 - 8.6	8.3	8.5	8.1 - 8.4	8.2	8.3
[illegible]	42. - 93.	68.	67.	56. - 86.	73.	68.	75. - 131.	96.	91.
[illegible]	0.314 - 0.385	0.353	0.351	0.312 - 0.389	0.351	0.355	0.331 - 0.354	0.339	0.335
[illegible]	0.359 - 0.439	0.402	0.401	0.365 - 0.399	0.409	0.403	0.384 - 0.439	0.409	0.402
[illegible]	0.391 - 0.445	0.421	0.425	0.339 - 0.439	0.421	0.429	0.339 - 0.439	0.419	0.421
[illegible]	0.339 - 0.398	0.375	0.378	0.339 - 0.398	0.403	0.405	0.339 - 0.398	0.375	0.378
[illegible]	0.299 - 0.339	0.317	0.318	0.299 - 0.339	0.323	0.319	0.299 - 0.339	0.321	0.319
[illegible]	0.340 - 0.378	0.357	0.354	0.340 - 0.378	0.354	0.349	0.340 - 0.393	0.354	0.349
[illegible]	0.279 - 0.439	0.339	0.335	0.279 - 0.439	0.346	0.339	0.299 - 0.439	0.339	0.339
[illegible]	3.3 - 4.4	3.3	3.3	4.3 - 13.4	7.8	7.8	3.4 - 3.4	3.1	3.4
[illegible]	4.3 - 4.3	4.1	4.1	8.5 - 4.1	3.8	3.2	3.8 - 4.3	3.8	3.3

3. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
07/30/75	1. Chroomonas sp.	171
	2. Fragilaria sp.	120
	3. Aphanizomenon sp.	86
	4. Anabaena sp.	86
	5. Aphanothece sp.	86
	Other genera	42
	Total	599
09/03/75	1. Fragilaria sp.	316
	2. Chroomonas sp.	201
	3. Asterionella sp.	106
	4. Cryptomonas sp.	70
	5. Stephanodiscus sp.	35
	Other genera	185
	Total	912
10/20/75	1. Melosira sp.	420
	2. Microcystis sp.	86
	3. Schroederia sp.	86
	4. Chroomonas sp.	86
	5. Komphosphaeria sp.	43
	Other genera	169
	Total	896

2. Chlorophyll A -

Sampling Date	Station Number	Chlorophyll a (ug/l)
07/30/75	1	2.0
	2	3.5
	3	4.4
	4	3.2
09/03/75	1	8.6
	2	7.1
	3	11.4
	4	4.3
10/20/75	1	0.8
	2	1.0
	3	2.4
	4	0.4

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l dry wt.)
Control	0.015	0.015	1.2
0.050 P	0.065	0.015	2.3
0.050 P + 1.0 N	0.065	1.015	26.4
1.0 N	0.015	1.015	4.0

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Hebgen Lake was moderate at the time the sample was taken (07/30/75). Also, lack of yield response with the addition of phosphorus until nitrogen also was added indicates the lake was nitrogen limited at that time. Note that the addition of only nitrogen resulted in a yield significantly greater than that of the control.

The lake data also indicate nitrogen limitation. The mean inorganic nitrogen/orthophosphorus ratios were 7/1 or less at all sampling stations and times, and nitrogen limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Montana National Guard collected monthly near-surface grab samples when possible from each of the tributary sites indicated on the map (page v). Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Montana District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Denny Creek at station D-1 and the mean annual ZZ flow.

No known wastewater treatment plants impacted Hebgen Lake during the sampling year.

A. Waste Sources:

1. Known municipal - None
2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Madison River	14,605	60.0
Watkins Creek	30	0.1
S. Fk. Madison River	2,470	10.2
Duck Creek	1,405	5.8
b. Minor tributaries & immediate drainage (non-point load) -	4,815	19.9
c. Known municipal STP's - None	-	-
d. Septic tanks* -	55	0.3
e. Known industrial - None	-	-
f. Direct precipitation** - None	805	3.3
Total	24,175	100.0

2. Outputs -

Lake outlet - Madison River 20,550

3. Net annual P accumulation - 3,625 kg.

* Estimate based on 96 permanent lakeshore dwellings and 5 campgrounds; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Madison River	244,420	36.9
Watkins Creek	1,045	0.2
S. Fk. Madison River	94,075	14.2
Buck Creek	40,360	6.1
b. Minor tributaries & immediate drainage (non-point load) -	225,760	34.0
c. Known municipal STP's - None	-	-
d. Septic tanks* -	1,985	0.3
e. Known industrial - None	-	-
f. Direct precipitation** -	55,350	8.3
Total	663,030	100.0

2. Outputs -

Lake outlet - Madison River 691,505

3. Net annual N loss - 28,904 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Madison River	13	211
Watkins Creek	1	36
S. Fk. Madison River	12	445
Buck Creek	5	132

* Estimate based on 96 permanent lakeshore dwellings and 5 campgrounds; see Working Paper No. 175.
** See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Denny Creek	0.016	0.790
Cougar Creek	0.029	0.556

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.47	0.07	12.9	loss*

Vollenweider phosphorus loadings (g/m^2/yr) based on mean depth and mean hydraulic retention time of Hebgen Lake:

"Dangerous" (eutrophic loading)	0.80
"Permissible" (oligotrophic loading)	0.40

* There was an apparent loss of nitrogen during the sampling year. This may have been due to nitrogen fixation in the lake, solubilization of previously sedimented nitrogen, recharge with nitrogen rich ground water, or unknown and unsampled point sources discharging directly to the lake. Whatever the cause, a similar loss has occurred at Shagawa Lake, Minnesota, which has been intensively studied by EPA's former National Eutrophication and Lake Restoration Branch (Malueg et al., 1975).

V. LITERATURE REVIEWED

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VI. APPENDICES

APPENDIX A

LAKE RANKINGS

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LAKES RANKED BY [illegible]

RANK	LAKE CODE	LAKE NAME	[illegible]
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14	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

M

APPENDIX C

TRIBUTARY FLOW DATA

20

APPENDIX D

PHYSICAL and CHEMICAL DATA

[illegible]

APPENDIX E

TRIBUTARY DATA

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34.